

2001 UPDATE

**ASSEMBLY BILL 970
DRAFT
NONRESIDENTIAL BUILDING
ENERGY EFFICIENCY
STANDARDS**

CONTRACTOR'S REPORT

VOLUME 4 - IMPACT ANALYSIS

November 2000
P400-00-025/ V4



Gray Davis, Governor

CALIFORNIA ENERGY COMMISSION

Prepared By:

Eley Associates
Charles Eley
San Francisco, CA
Contract No. 400-00-005, Amendment 1

Prepared For:

Donald Kazama

Contract Manager

G. William Pennington

Project Manager

Mike Sloss

Manager

Nonresidential Buildings Office

Scott W. Matthews

Deputy Director

Energy Efficiency Division

Steve Larson

Executive Director

**California Energy Commission
Assembly Bill 970 Building Energy Efficiency Standards**

Contractor Report

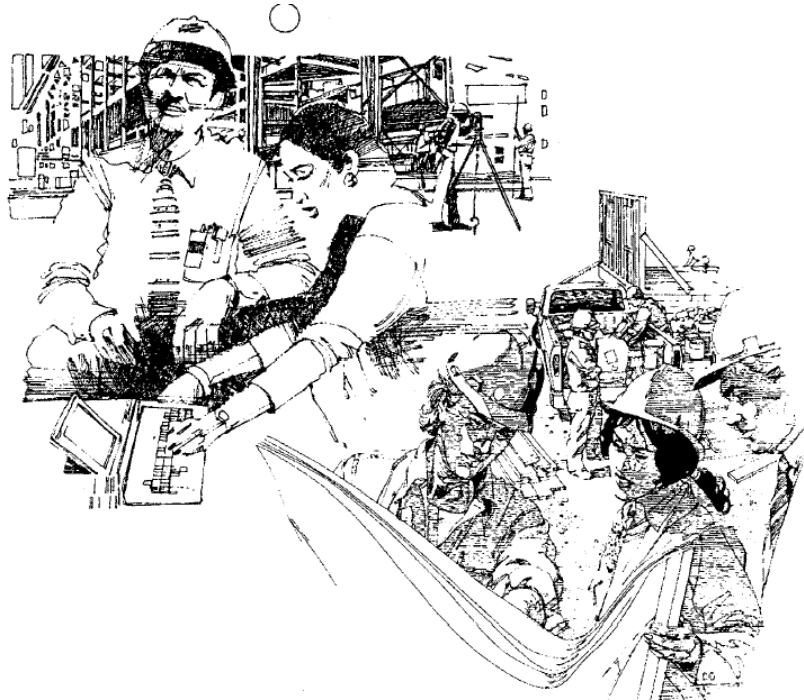
**2001 Update – AB 970 Draft Nonresidential
Building Standards**

**Energy Commission Publication No. P 400-00-025/V4
Impact Analysis**

This Contractor Report, prepared by Eley Associates, is an impact analysis that estimates statewide natural gas and electricity savings that will result from the proposed changes to the Nonresidential Building Energy Efficiency Standards. This report is intended for discussion at an Efficiency Standards Committee hearing on November 28, 2000. The hearing purpose is to obtain public comment on this report and revisions to the Title 24 Building Energy Efficiency Standards (California Code of Regulations, Title 24, Part 6).

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November 17, 2000



Volume IV – Impact Analysis

***Assembly Bill 970 Emergency Rulemaking –
2001 Update of California Nonresidential
Building Energy Efficiency Standards***

November 17, 2000



California Energy Commission
Don Kazama, Contract Manager

Contract Number 400-00-005
Task 5 – Impact Analysis



Architectural Energy Corporation
www.archenergy.com

Under subcontract to:
Eley Associates

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Introduction

The purpose of this task is to estimate the statewide impacts of the proposed standards amendments. The primary purpose of the impact analysis is to provide input to the required Environmental Impact Report on the electricity and gas impacts of the proposed changes on a regional and statewide basis.

NRNC Database

The statewide impacts were projected using the California Statewide NRNC database¹, a collection of 990 buildings statistically selected to represent the majority of statewide NRNC activity. The buildings in the database represent the building types considered by the CEC in their non-residential sector forecasting models, with the exception of refrigerated warehouses, which are not covered under Title 24. The majority of the data come from about 880 on-site surveys conducted during impact evaluation studies of the SCE and PG&E 1994 and 1996 NRNC energy efficiency programs. These data were supplemented with thirty audits from the impact evaluation of the 1995 SDG&E NRNC program and additional on-site surveys designed to supplement the existing data. Participants in utility energy-efficiency programs are included, but are weighted according to their general representation in the population. The population was defined using a listing of new construction projects obtained from F. W. Dodge. The Dodge database seeks to list all new construction projects that are valued over \$200,000 and are expected to start within 60 days. The data include renovations and expansions as well as entirely new buildings.² These data were filtered to exclude projects not covered under Title 24. The population-weighted square footage distribution of audited sites in the NRNC database is shown by building type in Figure 1. These data are compared to estimates of new construction activity in 2001 supplied by the CEC.

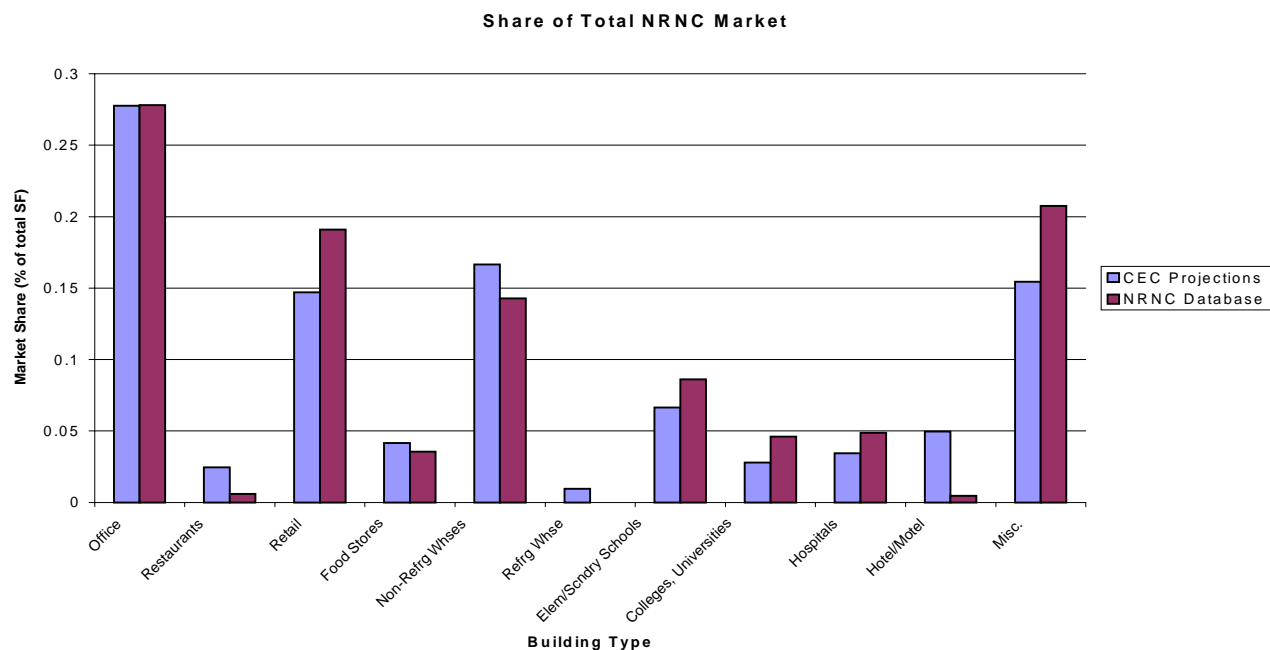


Figure 1. Estimates of NRNC Construction Activity by Building Type

Note, the market share distribution in the NRNC database and the CEC projections are fairly close in most important market categories. Notable exceptions are the Restaurant and Hotel/Motel sectors, which generally do not comprise a large fraction of the total NRNC activity. Hotels and Motels were excluded from the analysis due to the poor coverage of this building type in the NRNC data. Refrigerated warehouses are not considered, since they are not covered under Title 24.

¹ RLW Analytics et al, *California Non-residential New Construction Baseline Study*, California Board for Energy Efficiency, 1999.

² The data is thought to cover over 95% of all projects that are competitively bid.

During the audits information on building physical characteristics such as types of lighting and plug load inventories, types and efficiency of HVAC equipment, insulation levels, and glazing properties were collected. Building occupants were interviewed to determine behavior characteristics such as occupancy schedules and equipment operation. The on-site data were used to develop DOE-2 building energy simulation models through an automated modeling process. Most building simulation models were calibrated to monthly billing data when the data were available.

The NRNC data represent the broad range of construction practices, climate zones and occupant behavior expected in a building population as diverse as the NRNC market. For example, the office segment contains a wide variety of buildings ranging from glass and steel skyscrapers to one-story wood frame buildings. Each site in the sample has a statistically derived sample weight and precision, expressing the relative representation of each building in the NRNC population, thus allowing the results obtained from simulations of each individual building to be projected to the population with a quantifiable level of precision.

Modeling Procedure

An automated modeling process was used to create DOE-2 models from the building characteristics data. Details of the on-site data collection and modeling procedures are given in Appendix A. Proposed provisions for the 2001 update of Title 24 were incorporated into the modeling software, and each building was simulated under two sets of conditions:

1. **1998 Title 24.** The building envelope characteristics, mechanical equipment efficiencies, and lighting power densities were set to the minimally compliant Title 24 condition as defined by the 1998 version of the Standard. Lighting and HVAC operating schedules were simulated in the as-surveyed condition. The area category method based on the observed occupancy was used to determine the LPD in all spaces. Provisions were added to the software to make the models responsive to new provisions proposed for the 2001 update.
2. **2001 Update.** The building envelope characteristics, mechanical equipment efficiencies, and lighting power densities were set to the minimally compliant Title 24 condition as defined by the proposed 2001 update of the Standard. Lighting and HVAC operating schedules were simulated in the as-surveyed condition. The area category method based on the observed occupancy was used to determine the LPD in all spaces.

Measure Implementation

New Title 24 requirements, and described in Volume I of this report were programmed into the automated modeling software. The analysis is summarized below:

Envelope.

Changes to the vertical fenestration criteria as a function of orientation and window wall ratio were implemented. The 2001 update considers glass and plastic skylights, with and without a curb. The skylight glazing type and curb was not recorded in the NRNC database, so all skylights were assumed to be curb-mounted plastic skylights in the analysis.

Mechanical.

Mechanical provisions described in Volume I were implemented. The measures covered include:

- Unitary air conditioning, heat pump, and electric chiller efficiency
- Cooling tower fan control and efficiency
- Absorption chiller efficiency
- Furnace and unit heater off-cycle controls
- Demand controlled ventilation

Duct sealing measures were not simulated, since these are implemented on an “equal energy tradeoff” basis. New provisions proposed for the 2001 update for equipment not covered under the 1998 Standards were simulated as summarized in Table 1 below:

Table 1. Baseline Assumptions for Measures not Covered Under 1998 Standards

Equipment	Performance Parameter	1998 Standard	2001 Standard	Notes
Cooling Towers	Fan speed control	Single speed	Two speed	
	Specific fan power	31.9 gpm/hp	38.2 gpm/hp	
Absorption Chillers	COP	0.95	1.0	Chiller type not know – 2 stage, direct fired chiller assumed.
Gas furnaces in conditioned spaces	Efficiency	0.80	0.81	1% efficiency improvement for vent damper. Applied to furnaces and unit heaters > 225 kBtu/hr capacity

Demand controlled ventilation was simulated in all spaces with occupancy greater than 10 SF/person, which includes auditorium, churches/chapels, main entry lobby, motion picture theater, and performance theater spaces. Outside air was scheduled to follow the space occupancy schedule data collected during the onsite survey. Hourly outdoor air quantities were calculated using 15 CFM/person applied to the hourly occupancy of the space. Minimum ventilation was limited to 0.15 CFM/SF regardless of occupancy.

Lighting

Changes to allowed lighting power densities for conference/meeting/multipurpose rooms, hotel lobbies and locker/dressing rooms were implemented as described in Volume I. A 3% credit for bi-level switching was applied to all spaces with occupancy sensors or central lighting controls, except in spaces with an allowed lighting power density of less than 0.8 W/SF. An additional 5% credit for automatic shutoff controls was applied to all spaces < 5000 SF.

HVAC System Re-sizing

HVAC system sizing for each building was determined by direct observation of the nameplate capacities of the HVAC equipment. The installed HVAC system capacity was compared to the design loads imposed on the system to determine a sizing ratio for each building. Once established, the sizing ratio was held constant for each subsequent DOE-2 run. A separate sizing run was done prior to the 1998 and 2001 baseline runs, using the equipment sizing algorithms in DOE-2. The system capacity for each was reset using the calculated peak cooling capacity, and the as-built sizing ratio, thus considering the impacts of changes to the standard on HVAC system size.

Impact Results

Statewide Impacts

Comparison of the buildings run under the 1998 and proposed 2001 update are summarized in Table 2 below. These results were projected into an estimated 156.6 million SF of NRNC activity for 2001.

Table 2 Statewide Projection of Impacts

Parameter	Impact per SF	Relative Precision	Statewide Impact	Error Bound
Electricity Consumption	0.485 kWh/SF	12.9%	75.9 GWh	9.8 GWh
Electricity Demand	0.403 W/SF	10.5%	63.1 MW	6.6 MW
Gas	450.0 Btu/SF	34.6%	704,873 therm	244,206 therm

The relative precision of each estimate was calculated by RLW Analytics, and considers the sampling size and variability of each parameter across the sample. The relative precision of the estimate was projected into the statewide impacts to give the error bounds reported above. Demand savings are based on the “building demand,” and consider the maximum demand savings at any of the hour of the year.

The end-use contribution of total statewide electricity consumption and demand impacts are shown in Figures 2 and 3 below.

End Use Distribution of kWh Savings

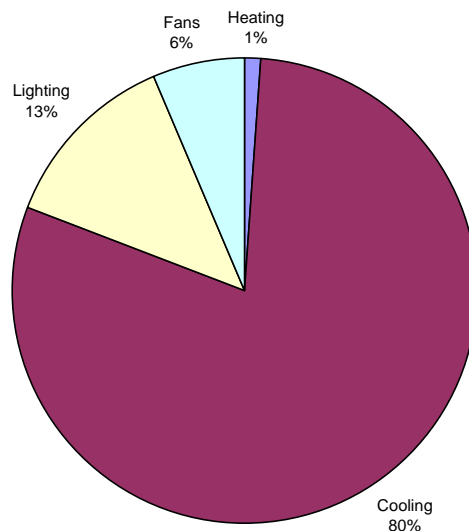
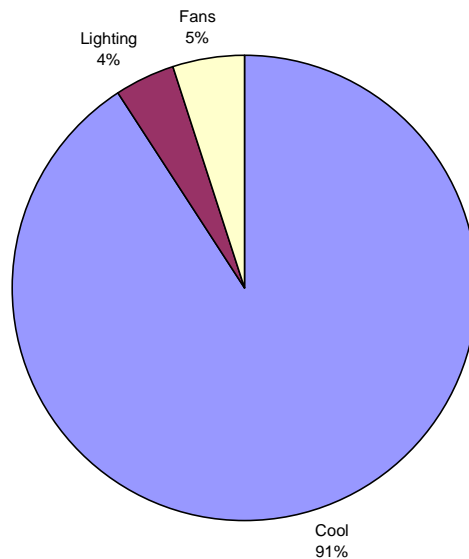


Figure 2 – End Use Distribution of kWh savings

End-Use Distribution of Peak Savings*Figure 3 – End Use Distribution of kW savings*

Gas impacts were primarily in the heating end-use, with a very small impact in the cooling end-use, reflecting the small representation of gas absorption cooling in the NRNC data.

Impacts by Climate Zone

Energy, demand and gas impacts were disaggregated by climate region. The results are reported in Tables 3 through 5 below. The relative precision of these results is much worse than the statewide estimates, due to smaller sample sizes in each climate zone, and the variability in the impacts per SF inherent in NRNC building performance.

Table 3 – Electricity Consumption Impacts by Climate Zone

Climate Zone	SAMPLE SIZE	Savings (kWh/SF)	Relative Precision	SF	GWh Savings	Error Bound
1	6	0.119	63.5%	492,518	0.06	0.04
2	35	0.205	37.8%	10,987,070	2.25	0.85
3	155	0.326	14.8%	24,852,706	8.11	1.20
4	88	0.635	29.3%	11,160,223	7.08	2.08
5	20	0.252	72.6%	2,929,968	0.74	0.54
6	91	0.356	36.7%	9,422,700	3.35	1.23
7	41	1.258	19.5%	11,687,285	14.71	2.86
8	75	0.560	39.6%	13,721,366	7.69	3.04
9	86	0.448	53.3%	16,232,548	7.28	3.88
10	76	0.443	29.9%	13,202,809	5.85	1.75
11	37	0.199	35.4%	2,186,251	0.44	0.15
12	125	0.357	24.8%	22,704,019	8.10	2.01
13	80	0.383	88.0%	9,339,987	3.58	3.15
14	46	0.259	38.4%	3,751,282	0.97	0.37
15	20	0.557	36.7%	3,098,502	1.73	0.63
16	4	0.202	103.0%	853,767	0.17	0.18

Table 4 Electricity Demand Impacts by Climate Zone

Climate Zone	SAMPLE SIZE	Savings (W/SF)	Relative Precision	SF	MW Savings	Error Bound
1	6	0.115	73.2%	492,518	0.06	0.04
2	35	0.214	40.2%	10,987,070	2.35	0.94
3	155	0.267	15.5%	24,852,706	6.62	1.03
4	88	0.426	21.6%	11,160,223	4.76	1.03
5	20	0.177	88.6%	2,929,968	0.52	0.46
6	91	0.215	35.7%	9,422,700	2.02	0.72
7	41	0.673	26.6%	11,687,285	7.87	2.10
8	75	0.337	39.0%	13,721,366	4.62	1.80
9	86	0.254	39.8%	16,232,548	4.12	1.64
10	76	0.304	28.4%	13,202,809	4.02	1.14
11	37	0.167	32.3%	2,186,251	0.36	0.12
12	125	0.298	23.0%	22,704,019	6.77	1.56
13	80	0.140	39.9%	9,339,987	1.31	0.52
14	46	0.237	27.1%	3,751,282	0.89	0.24
15	20	0.311	34.2%	3,098,502	0.96	0.33
16	4	0.094	91.7%	853,767	0.08	0.07

Table 5 Gas Consumption Impacts by Climate Zone

Climate	SAMPLE	Savings	Relative	SF	Therm	Error Bound
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Zone	SIZE	(Btu/SF)	Precision		Savings	
1	6	190.0	101.6%	492,518	936	951
2	35	591.8	59.6%	10,987,070	65,020	38,724
3	155	354.5	44.5%	24,852,706	88,100	39,217
4	88	-5.1	-7090.0%	11,160,223	-565	40,051
5	20	56.2	52.9%	2,929,968	1,647	871
6	91	19.6	419.5%	9,422,700	1,852	7,768
7	41	486.2	171.1%	11,687,285	56,826	97,244
8	75	119.8	57.7%	13,721,366	16,440	9,489
9	86	758.7	123.4%	16,232,548	123,153	151,983
10	76	292.7	63.8%	13,202,809	38,641	24,661
11	37	1,281.7	80.1%	2,186,251	28,022	22,444
12	125	920.7	51.6%	22,704,019	209,035	107,915
13	80	743.6	91.8%	9,339,987	69,449	63,742
14	46	194.7	149.6%	3,751,282	7,304	10,925
15	20	70.2	77.4%	3,098,502	2,174	1,682
16	4	95.4	48.0%	853,767	815	391

Appendix A On-Site Survey and Modeling Procedure

On-Site Surveys

The primary data source for the DOE-2 models was the on-site survey. The survey form was designed so that key modeling decisions on model zoning and equipment/space association were made by the surveyors in the field. The form was designed to follow the logical progression of an on-site survey process. The form started out with a series of interview questions. Conducting the interview first helped orient the surveyor to the building and allowed time for the surveyor to establish a rapport with the customer. Once the interview was completed, an inventory of building equipment was conducted. The survey started with the HVAC systems, and progressed from the roof and/or other mechanical spaces into the conditioned spaces. This progression allowed the surveyor to establish the linkages between the HVAC equipment and the spaces served by the equipment. The incented measures were identified during the on-site audit.

Interview Questions

The surveyor used the interview questions to identify building characteristics and operating parameters that were not observable during the course of the on-site survey. The interview questions covered the following topics:

Building functional areas. Functional areas were defined on the basis of operating schedules. Subsequent questions regarding occupancy, lighting, and equipment schedules, were repeated for each functional area.

Occupancy history. The occupancy history questions were used to establish the vacancy rate of the building during 1998. The questions covered occupancy, as a percent of total surveyed floor space, and HVAC operation during the tenant finish and occupancy of the space. Responses to these questions were used to understand building start-up behavior during the model calibration process.

Building Occupancy schedules. For each functional area in the building, a set of questions were asked to establish the building occupancy schedules. First, the surveyor assigned each day of the week to one of three daytypes: full occupancy, partial occupancy, and unoccupied. This was done to cover buildings that did not operate on a normal Monday through Friday workweek. Holidays and monthly variability in occupancy schedules were identified.

Daily schedules for occupants, interior lighting, and equipment/plug loads. A set of questions was used to establish hourly occupancy, interior lighting, and miscellaneous equipment and plug load schedules for each functional area in the building. During the on-site survey, the surveyor defined hourly schedules for each daytype. A value, which represents the fraction of the maximum occupancy and/or connected load was entered for each hour of the day. The entry of the schedule onto the form was done graphically.

Daily schedules of kitchen equipment. A set of questions were asked to establish hourly kitchen equipment schedules for each functional area in the building for each daytype. A value which represented the equipment-operating mode (off, idle, or low, medium or high volume production) was entered for each hour of the day. The entry of the schedule onto the form was done graphically.

Operation of other miscellaneous systems. General questions on the operation of exterior lighting systems, interior lighting controls, window shading, swimming pools, and spas were covered in this section.

Operation of the HVAC systems. A series of questions were asked to construct operating schedules for the HVAC systems serving each area. The surveyors entered fan operating schedules and heating and cooling setpoints. A series of questions were used to define the HVAC system controls. These questions were intended to be answered by someone familiar with the operation of the building mechanical systems. The questions covered operation of the outdoor air ventilation system, supply air temperature controls, VAV system terminal box type, chiller and chilled water temperature controls, cooling tower controls, and water-side economizers.

Building-wide water use. A series of questions were used to help calculate the service hot water requirements for the building.

Refrigeration system. The operation of refrigeration systems utilizing remote condensers, which are common in groceries and restaurants, was covered in this section. Surveyors divided the systems into three temperature classes, (low, medium and high) depending on the compressor suction temperature. For each system temperature, the refrigerant, and predominant defrost mechanism was identified. Overall system controls strategies were also covered.

Building Characteristics

The next sections of the on-site survey covered observations on building equipment inventories and other physical characteristics. Observable information on HVAC systems, building shell, lighting, plug loads, and other building characteristics were entered, as described below:

Built-up HVAC systems. Make, model number, and other nameplate data were collected on the chillers, cooling towers, heating systems, air handlers, and pumps in the building. Air distribution system type, outdoor air controls, and fan volume controls were also identified.

Packaged HVAC systems. Equipment type, make, model number, and other nameplate data were collected on the packaged HVAC systems in the building.

Zones. Based on an understanding of the building layout and the HVAC equipment inventory, basic zoning decisions were made by the surveyors according to the following criteria:

- **Unusual internal gain conditions.** Spaces with unusual internal gain conditions, such as computer rooms, kitchens, laboratories were defined as separate zones.
- **Operating schedules.** Occupant behavior varies within spaces of nominally equivalent use. For example, retail establishments in a strip retail store may have different operating hours. Office tenants may also have different office hours.
- **HVAC system type and zoning.** When the HVAC systems serving a particular space were different, the surveyors sub-divided the spaces according to HVAC system type. If the space was zoned by exposure, the space was surveyed as a single zone, and a “zone by exposure” option was selected on the survey form.

For each zone defined, the surveyor recorded the floor area and occupancy type. Enclosing surfaces were surveyed, in terms of surface area, construction type code, orientation, and observed insulation levels. Window areas were surveyed by orientation. The surveyor also identified and inventoried basic window properties, interior and exterior shading devices, lighting fixtures and controls, and miscellaneous equipment and plug loads. Finally, the surveyor identified and entered zone-level HVAC equipment, such as baseboard heaters, fan coils, and VAV terminals.

Refrigeration systems. The surveyor inventoried the refrigeration equipment separately, and associated the equipment with a particular zone in the building. Refrigerated cases and stand-alone refrigerators were identified by case type, size, product stored, and manufacturer. Remote compressor systems were inventoried by make, model number, and compressor system type. Each compressor or compressor rack was associated with a refrigerated case temperature loop and heat rejection equipment such as a remote condenser, cooling tower, and/or HVAC system air handler. Remote condensers were inventoried by make, model number, and type. Nameplate data on fan and pump hp were recorded. Observations on condenser fan speed controls were also recorded.

Cooking Equipment. The surveyor recorded the cooking equipment separately and associated with a particular zone in the building. Major equipment was inventoried by equipment type (broiler, fryer, oven, and so on), size, and fuel type. Kitchen ventilation hoods were inventoried by type and size. Nameplate data on exhaust flowrate and fan hp were recorded and each piece of kitchen equipment was associated with a particular ventilation hood.

Hot Water/ Pools. Water heating equipment was inventoried by system type, capacity, and fuel type. The surveyor recorded observations on delivery temperature, heat recovery, and circulation pump horsepower. Solar water heating equipment was inventoried by system type, collector area, and collector tilt and storage

capacity. The surveyor inventoried pools and spas by surface area and location (indoor or outdoor). The filter pump motor horsepower was recorded, along with the surface area, collector type, and collector tilt angle data for solar equipment serving pools and/or spas.

Miscellaneous exterior loads. Connected load, capacity, and other descriptive data on elevators, escalators, interior transformers, exterior lighting, and other miscellaneous equipment were recorded.

Meter Numbers. Additional data were collected in the field to assist in the billing data account matching and model calibration process. This section served as the primary link between the on-site survey and billing data for non-participants. The surveyor recorded meter numbers for each meter serving the surveyed space. If the meter served space in addition to the surveyed space, the surveyor made a judgment on the ratio of the surveyed space to the space served by the meter.

Establishing Component Relationships

In order to create a DOE-2 model of the building from the various information sources contained in the on-site survey, relationships between the information contained in the various parts of the survey needed to be established. In the interview portion of the form, schedule and operations data were cataloged by building functional area. In the equipment inventory section, individual pieces of HVAC equipment: boilers, chillers, air handlers, pumps, packaged equipment and so on were inventoried. In the zone section of the survey, building envelope data, lighting and plug load data, and zone-level HVAC data were collected. The following forms provided the information needed by the software to associate the schedule, equipment, and zone information.

System/Zone Association Checklist. The system/zone association checklist provided a link between each building zone and the HVAC equipment serving that zone. Systems were defined in terms of a collection of packaged equipment, air handlers, chillers, towers, heating systems, and pumps. Each system was assigned to the appropriate thermal zones in accordance with the observed building design.

Interview “Area” / Audit “Zone” Association Checklist. Schedule and operations data gathered during the interview phase of the survey were linked to the appropriate building zone. These data were gathered according to the building functional areas defined previously. Each building functional area could contain multiple zones. This table facilitated the association of the functional areas to the zones, and thereby the assignment of the appropriate schedule to each zone.

Modeling Procedures

An automated process was used to develop basic DOE-2 models from data contained in the on-site surveys, Title 24 compliance forms, program information and other engineering data. The modeling software took information from these data sources and created a DOE-2 model. The data elements used, default assumptions, and engineering calculations are described for the Loads, Systems, and Plant portions of the DOE-2 input file as follows.

Loads

Schedules were created for each zone in the model by associating the zones defined in the on-site survey with the appropriate functional area, and assigning the schedule defined for each functional area to the appropriate zone. Hourly schedules were created by the software on a zone-by-zone basis for:

- Occupancy
- Lighting
- Electric equipment
- Gas equipment (primarily kitchen equipment)
- Solar glare
- Window shading
- Infiltration

Occupancy, lighting, and equipment schedules. Each day of the week was assigned to a particular daytype, as reported by the surveyor. Hourly values for each day of the week were extracted from the on-site database according to the appropriate daytype. These values were modified on a monthly basis, according to the monthly building occupancy history.

Solar and shading schedules. The use of blinds by the occupants was simulated by the use of solar and shading schedules. The glass shading coefficient values were modified to account for the use of interior shading devices.

Infiltration schedule. The infiltration schedule was established from the fan system schedule. Infiltration was scheduled “off” during fan system operation, and was scheduled “on” when the fan system was off.

Shell materials. A single-layer, homogeneous material was described which contains the conductance and heat capacity properties of the composite wall used in the building. The thermal conductance and heat capacity of each wall and roof assembly was taken from the Title 24 documents, when available. If the Title 24 documents were not available, default values for the conductance and heat capacity were assigned from the wall and roof types specified in the on-site survey, and the observed R-values. If the R-values were not observed during the on-site survey and the Title 24 documents were not available, an “energy-neutral” approach was taken by assigning the same U-value and heat capacity for the as-built and Title 24 simulation runs.

Windows. Window thermal and optical properties from the building drawings or Title 24 documents (when available) were used to develop the DOE-2 inputs. If these documents were not available, default values for the glass conductance were assigned according to the glass type specified in the on-site survey. If the glass type was not observed during the on-site survey and the Title 24 documents were not available, an “energy-neutral” approach was taken by assigning the same U-value and shading coefficient for the as-built and Title 24 simulation runs.

Lighting kW. Installed lighting power was calculated from the lighting fixture inventory reported on the survey. A standard fixture wattage was assigned to each fixture type identified by the surveyors. Lighting fixtures were identified by lamp type, number of lamps per fixture, and ballast type as appropriate.

Lighting controls. The presence of lighting controls was identified in the on-site survey. For occupancy sensor and lumen maintenance controls, the impact of these controls on lighting consumption was simulated as a reduction in connected load, according to the Title 24 lighting control credits. Daylighting controls were simulated using the “functions” utility in the load portion of DOE-2. Since the interior walls of the zones were not surveyed, it was not possible to use the standard DOE-2 algorithms for simulating the daylighting illuminance in the space. A daylight factor, defined as the ratio of the interior illuminance at the daylighting control point to the global horizontal illuminance was estimated for each zone subject to daylighting control. Typical values for sidelighting applications were used as default values. The daylight factor was entered into the function portion of the DOE-2 input file. Standard DOE-2 inputs for daylighting control specifications were used to simulate the impacts of daylighting controls on lighting schedules. The default daylight factors were adjusted during model calibration.

Equipment kW. Connected loads for equipment located in the conditioned space, including miscellaneous equipment and plug loads, kitchen equipment and refrigeration systems with integral condensers were calculated. Input data were based on the “nameplate” or total connected load. The nameplate data were adjusted using a “rated-load factor,” which is the ratio of the average operating load to the nameplate load during the definition of the equipment schedules. This adjusted value represented the hourly running load of all equipment surveyed. Equipment diversity was also accounted for in the schedule definition.

For the miscellaneous equipment and plug loads, equipment counts and connected loads were taken from the on-site survey. When the connected loads were not observed, default values based on equipment type were used.

For the kitchen equipment, equipment counts and connected loads were taken from the on-site survey. Where the connected loads were not observed, default values based on equipment type and “trade size” were used. Unlike the miscellaneous plug load schedules, the kitchen equipment schedules were defined by operating regime. An hourly value corresponding to “off”, “idle”, or “low,” “medium,” or “high” production rates

were assigned by the surveyor. The hourly schedule was developed from the reported hourly operating status and the ratio of the hourly average running load to the connected load for each of the operating regimes.

For the refrigeration equipment, refrigerator type, count, and size were taken from the on-site survey. Equipment observed to have an “integral” compressor/condenser that is, equipment that rejects heat to the conditioned space, were assigned a connected load per unit size.

Source input energy. Source input energy represented all non-electric equipment in the conditioned space. In the model, the source type was set to natural gas, and a total input energy was specified in terms of Btu/hr. Sources of internal heat gains to the space that were not electrically powered include kitchen equipment, dryers, and other miscellaneous process loads. The input rating of the equipment was entered by the surveyors. As with the electrical equipment, the ratio of the rated input energy to the actual hourly consumption was calculated by the rated load factor assigned by equipment type and operating regime.

Heat gains to space. The heat gains to space were calculated based on the actual running loads and an assessment of the proportion of the input energy that contributed to sensible and latent heat gains. This in turn depended on whether or not the equipment was located under a ventilation hood.

Spaces. Each space in the DOE-2 model corresponded to a zone defined in the on-site survey. In the instance where the “zoned by exposure” option was selected by the surveyor, additional DOE-2 zones were created. The space conditions parameters developed on a zone by zone basis were included in the description of each space. Enclosing surfaces, as defined by the on-site surveyors, were also defined.

Systems

This section describes the methodology used to develop DOE-2 input for the systems simulation. Principal data sources include the on-site survey, Title 24 documents, manufacturers’ data, and other engineering references as listed in this section.

Fan schedules. Each day of the week was assigned to a particular daytype, as reported by the surveyor. The fan system on and off times from the on-site survey was assigned to a schedule according to daytype. These values were modified on a monthly basis, according to the monthly HVAC operating hour adjustment. The on and off times were adjusted equally until the required adjustment percentage was achieved. For example, if the original schedule was “on” at 6:00 hours and “off” at 18:00 hours, and the monthly HVAC adjustment indicated that HVAC operated at 50% of normal in June, then the operating hours were reduced by 50% by moving the “on” time up to 9:00 hours and the “off” time back to 15:00 hours.

Setback schedules. Similarly, thermostat setback schedules were created based on the responses to the on-site survey. Each day of the week was assigned to a particular daytype. The thermostat setpoints for heating and cooling, and the setback temperatures and times were defined according to the responses. The return from setback and go to setback time was modified on a monthly basis in the same manner as the fan-operating schedule.

Exterior lighting schedule. The exterior lighting schedule was developed from the responses to the on-site survey. If the exterior lighting was controlled by a time clock, the schedule was used as entered by the surveyor. If the exterior lighting was controlled by a photocell, a schedule, which follows the annual variation in daylength, was used.

System type. The HVAC system type was defined from the system description from the on-site survey. The following DOE-2 system types were employed:

- Packaged single zone (PSZ)
- Packaged VAV (PVAVS)
- Packaged terminal air conditioner (PTAC)
- Water loop heat pump (HP)
- Evaporative cooling system (EVAP-COOL)
- Central constant volume system (RHFS)

- Central VAV system (VAVS)
- Central VAV with fan-powered terminal boxes (PIU)
- Dual duct system (DDS)
- Multi-zone system (MZS)
- Unit heater (UHT)
- Four-pipe fan coil (FPFC)

Packaged HVAC system efficiency. Manufacturers' data were gathered for the equipment surveyed based on the observed make and model number. A database of equipment efficiency and capacity data was developed from an electronic version of the ARI rating catalog. Additional data were obtained directly from manufacturers' catalogs, or the on-line catalog available on the ARI website (www.ari.org). Manufacturers' data on packaged system efficiency is a net efficiency, which considers both fan and compressor energy. DOE-2 requires a specification of packaged system efficiency that considers the compressor and fan power separately. Thus, the manufacturers' data were adjusted to prevent "double-accounting" of fan energy, according to the procedures described in the 1995 Alternate Compliance Method (ACM) manual.

Pumps and fans. Input power for pumps, fans and other motor-driven equipment was calculated from motor nameplate hp data. Motor efficiencies as observed by the surveyors were used to calculate input power. In the absence of motor efficiency observations, standard motor efficiencies were assigned as a function of the motor hp, RPM and frame type. A rated load factor was used to adjust the nameplate input rating to the actual running load. For VAV system fans, custom curves were used to calculate fan power requirements as a function of flow rate in lieu of the standard curves used in DOE-2, as described in the 1995 ACM manual.

Refrigeration systems. Refrigeration display cases and/or walk-ins were grouped into three systems defined by their evaporator temperatures. Ice cream cases were assigned to the lowest temperature circuit, followed by frozen food cases, and all other cases. Case refrigeration loads per lineal foot were taken from manufacturers' catalog data for typical cases. Auxiliary energy requirement data for evaporator fans, anti-sweat heaters, and lighting were also compiled from manufacturers' catalog data. Model inputs were calculated based on the survey responses. For example, if the display lighting was surveyed with T-8 lamps, lighting energy requirements appropriate for T-8 lamps were used to derive the case auxiliary energy input to DOE-2.

Compressor EER data were obtained from manufacturers' catalogs as a function of the suction temperatures corresponding to each of the three systems defined above. These data were used to create default efficiencies for each compressor system. Custom part-load curves were used to simulate the performance of parallel-unequal rack systems.

Total heat of rejection (THR) data at design conditions were obtained for refrigeration system condensers from manufacturers' data. These data were used to calculate hourly approach temperatures and fan energy using the enhanced refrigeration condenser algorithms in DOE-2.1 E version 119.

Service hot water. Service hot water consumption was calculated based on average daily values from the 1995 ACM for various occupancy types. Equipment capacity and efficiency were assigned based on survey responses.

Exterior lighting. Exterior lighting input parameters were developed similarly to those for interior lighting. The exterior lighting connected load was calculated from a fixture count, fixture identification code and the input wattage value associated with each fixture code.

Plant

This section describes the methodology used to develop DOE-2 input for the plant simulation. Principal data sources included the on-site survey, Title 24 documents, manufacturers' data, program data, and other engineering references.

Chillers. The DOE-2 input parameters required to model chiller performance included chiller type, full-load efficiency and capacity at rated conditions, and performance curves to adjust chiller performance for temperature and loading conditions different from the rated conditions. Chiller type was assigned based on the type code selected during the on-site survey. Surveyors also gathered chiller make, model number, and serial

number data. These data were used to develop performance data specific to the chiller installed in the building. Program data and/or manufacturers' data were used to develop the input specifications for chiller efficiency.

Cooling towers. Cooling tower fan and pump energy was defined based on the nameplate data gathered during the on-site survey. Condenser water temperature and fan volume control specifications were derived from the on-site survey responses.
